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ONTARIO

Department of Education

# Courses of Study

Grade 13

## CHEMISTRY

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## CHEMISTRY, GRADE 13

The Grade 13 course in Chemistry is a continuation of the course prescribed for Grade 12 Chemistry or Agricultural Science, Part II.

The outline is given in considerable detail to make the statement of the course as specific as possible and to provide the teacher with a definite guide as to the depth of treatment of each topic. The course is based on an allotment of five 40-minute periods a week.

The sequence of topics suggested is a logical one but it may be varied at the discretion of the teacher. Fundamental principles should be emphasized and every effort made to provide the student with an opportunity to take part in experimental work. It is also important that students should acquire some knowledge of what is commonly called the "scientific method" with its interdependence of ideas (theories, laws, etc.) and observations. Attention should be drawn to the fact that scientific ideas are continually evolving and changing and that laws and theories must often be abandoned or modified in the light of new observations and discoveries.

Good reference texts should be available in the classroom, and students should be encouraged to make use of them.

Attention should be drawn to the new system of nomenclature for inorganic compounds, as recommended by the International Union of Pure and Applied Chemistry. Instead of suffixes "ous" and "ic" the valence of the metal ion appears as a Roman numeral after the name of the element, for example, iron (III) chloride instead of ferric chloride. Both methods of naming compounds are in general use.

The students should be taught to appreciate the fact that all numbers obtained by measurement are approximate and that in any calculation involving measured quantities, the accuracy of the result will depend on the accuracy of the least exact factor in the calculation.

Throughout the entire course chemical equations are required for the experiments demanded. Students should be impressed with the fact that facility in the use of equations is expected in Grade 13.

### UNIT I. REVIEW (5 to 10 periods)

In order to give the students an opportunity to refresh their knowledge of the work taken in the previous course in Chemistry a short review is necessary. The review which follows covers those parts of the work of the previous course which might be required for the Grade 13 examination. The review topics may be taken at the beginning of the year or they may be introduced through the year as they are related to the new work in this course of study.

- (1) The classification of materials. The meaning of pure substance, element, compound, metal, non-metal, oxide, acid, base, salt, solution, mechanical mixture.
- (2) The following types of chemical reaction, with a specific example of each: oxidation, reduction, decomposition, combination, displacement, double-decomposition, exothermic and endothermic reactions.
- (3) The Law of Conservation of Mass, the Law of Definite Proportions, the Law of Reacting or Combining



- Weights, Gay-Lussac's Law of Combining Gas Volumes, Boyle's Law, Charles's Law, Avogadro's Law.
- (4) Definitions of (i) gram-equivalent weight and equivalent weight, (ii) gram-molecular weight and molecular weight (formula weight in the case of non-molecular compounds), (iii) gram-atomic weight and atomic weight, (iv) gram-molecular volume.
  - (5) Problems dealing with the determination of (i) the equivalent weight of an element from the composition of its oxide, (ii) the selection of atomic weight by Dulong and Petit's rule for specific heats, (iii) the simplest formula of a compound from its percentage composition, (iv) the percentage composition of a compound from its formula, (v) molecular weights and molecular formulas, (vi) the proportions by weight and by volume of the pure substances involved in chemical reactions from equations representing these reactions.

## UNIT II. RATE OF REACTION

(4 periods)

- (1) Meaning of rate of reaction.
- (2) Experiments to illustrate the effect of (i) temperature, (ii) concentration, (iii) state of subdivision, on rate of reaction as illustrated by the action of hydrochloric acid, 20% and 5%, hot and cold, on equal weights of zinc, iron, or marble in various states of subdivision.
- (3) Experiments to illustrate catalysis: (i) the effect of manganese dioxide on heated potassium chlorate, (ii) the effect of copper on the reaction of dilute sulphuric acid with zinc. (Metallic copper may be touched to the zinc, or copper sulphate may be added to the solution.)
- (4) The influence of each of the above factors may be illustrated by the action of oxalic acid and sulphuric acid on a solution of potassium permanganate.

The attention of the students should be drawn to the above factors as they may affect the rates of other reactions studied throughout this course.

## UNIT III. EQUILIBRIUM AND REVERSIBLE REACTIONS

(7 periods)

The concept of dynamic equilibrium and the principle of Le Chatelier, as illustrated in the following changes:

### A. *Physical Changes*

In each of the following examples discuss the reversibility of the change and establish the concept of equilibrium in a system involving reversible reactions:

- (1) Water in equilibrium with water vapour. Measurement of the vapour pressure of water by the introduction of a slight excess of liquid into the vacuum of a mercury barometer. The effect of change of temperature on vapour pressure and equilibrium, and the relationship between vapour pressure and boiling point. The definition of vapour pressure and of boiling point.

- (2) Bromine in equilibrium with bromine vapour; iodine (or naphthalene) in equilibrium with its vapour.
- (3) Ice in equilibrium with water. The definition of freezing point.
- (4) A solid in equilibrium with its saturated aqueous solution. This should serve as a point of review of the terms saturated solution, solubility, supersaturation.

#### B. *Chemical Changes*

The application of Le Chatelier's principle to the following examples, with a discussion of the factors—temperature, pressure, and concentration as they affect the relative amounts of the substances present at equilibrium:

- (1) Calcium carbonate in equilibrium with calcium oxide and carbon dioxide.
- (2) Nitrogen and hydrogen in equilibrium with ammonia (the Haber process).
- (3) Sulphur dioxide and oxygen in equilibrium with sulphur trioxide (the "contact" process of making sulphuric acid).

In addition to the foregoing examples, the student should understand Le Chatelier's principle well enough to apply it to other simple equilibria.

#### UNIT IV. THEORY OF ATOMIC STRUCTURE

(10 periods)

1. Dalton's Atomic Theory and its relationship to the Law of Conservation of Mass, the Law of Definite Proportions, the Law of Multiple Proportions, Gay-Lussac's Law of Volumes and Avogadro's Law. Reference should be made to any significant Grade 12 quantitative experimental work.
2. The contribution of the discovery of radioactivity to the modern concept of atomic structure.
3. The concept of the nuclear atom (Rutherford).
4. The modern concept of the atom in terms of the fundamental particles: protons, neutrons and electrons. Significance of the terms mass number and atomic number.
5. The arrangement of the electrons in the atom, specifically for elements with atomic numbers from one to twenty. The representation with schematic diagrams of the elements among these twenty which are studied in this course.
6. Formation of (i) the ions of ionic compounds by transfer of electrons to form stable octets, e.g.,  $\text{Na}^+$ ,  $\text{Mg}^{++}$ ,  $\text{Cl}^-$ ,  $\text{S}^{=}$ , (ii) crystals of ionic compounds as the symmetrical aggregation of ions held together by electrical attraction, e.g.,  $\text{Na}^+\text{Cl}^-$ ,  $\text{Ca}^{++}\text{Cl}^-\text{Cl}^-$ , (iii) the molecules of non-ionic compounds by sharing pairs of electrons, e.g.,  $\text{CH}_4$ ,  $\text{CCl}_4$ ,  $\text{NH}_3$ . Meaning of the terms ionic valence, ionic (electrovalent) bond, covalence, and covalent bond.
7. An account of the following, with explanations according to the modern atomic theory:



- (i) Isotopes, e.g.,  ${}_{17}\text{Cl}^{35}$ ,  ${}_{17}\text{Cl}^{37}$ ,  ${}_{1}\text{H}^1$ ,  ${}_{1}\text{H}^2$ ,  ${}_{1}\text{H}^3$ . Heavy water. The relation between the atomic weight of an element and the mass numbers of the isotopes that compose it.
- (ii) Natural radioactivity; alpha- and beta-particles, and gamma rays. The discovery, properties, and uses of radium (P. and M. Curie).
- (iii) The modern concept of the transmutation of elements by nuclear reactions; e.g., the production of radioactive isotopes of phosphorus and cobalt, and a discussion of how these may be used.
- (iv) The production of new elements, specifically plutonium. Statement and significance of Einstein's mass-energy relationship. The fission of certain heavy nuclei, specifically  $\text{U}^{235}$  and  $\text{Pu}^{239}$ , and the consequent release of enormous amounts of energy.

#### UNIT V. THEORY OF IONIZATION

(8 periods)

- (1) The meaning of terms electrolyte and non-electrolyte illustrated by experiment.
- (2) Arrhenius's theory of ionization.
- (3) Experiments to show the electrolysis of (i) copper (II) chloride solution, (ii) sodium chloride solution. The explanation of these in terms of the theory of ionization. The explanation of (ii) may be deferred until the topics of ionization of water and the activity series have been taught. (According to modern theory the liberation of hydrogen is brought about by the reduction of hydrogen ion which arises from the ionization of water. It requires less expenditure of energy to reduce hydrogen ion than sodium ion. No sodium metal is formed unless a mercury cathode is used.)
- (4) Properties of aqueous solutions of (i) acids, (ii) bases. Explanation of these properties in terms of hydrogen ion,  $\text{H}^+$ , or the hydronium ion,  $\text{H}_3\text{O}^+$  (an hydrated hydrogen ion), and the hydroxyl ion,  $\text{OH}^-$ .
- (5) The meaning of the terms "strong" and "weak" as applied to electrolytes in solutions of the same concentration. Strong electrolytes are those that are highly ionized in aqueous solution. Hydrochloric acid, nitric acid, sulphuric acid, sodium hydroxide, and most of the salts are examples of strong electrolytes. Acetic acid, carbonic acid, and ammonium hydroxide are representative weak electrolytes.
- (6) A demonstration to show that hydrochloric acid is a stronger acid than acetic acid (i) by means of an electrical conductivity experiment, (ii) by the action of these acids of the same normality, e.g., 4N, on (a) zinc, (b) sodium thiosulphate solution.  

$$\text{Na}_2\text{S}_2\text{O}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{SO}_2\uparrow + \text{S}\downarrow$$
- (7) Acidity in terms of hydrogen ion (or hydronium ion) concentration expressed as the number of gram-equiv-

alent weights of hydrogen ion per litre of solution. Reference to the pH scale. (Solutions with pH of less than 7 are acidic, those with a pH of more than 7 are basic, and those with a pH of 7 are neutral.)

- (8) Reference to the existence of ions in the solid and molten states of ionic compounds, e.g.,  $\text{Na}^+\text{Cl}^-$ ,  $\text{Ag}^+\text{NO}_3^-$ ,  $\text{Na}^+\text{C}_2\text{H}_3\text{O}_2^-$ ,  $\text{Mg}^{++}\text{O}^{=}$ . These compounds do not exist as molecules.

#### UNIT VI. SOLUBILITY RULES AND ACTIVITY SERIES

(4 periods)

- (1) General rules for the solubility in water of the following salts of the elements in the course: nitrates, chlorides, sulphates, carbonates, hydroxides, sulphides; and also salts of sodium, potassium, and ammonium.
- (2) The activity series (electrochemical series) of the common metallic elements and hydrogen.

Potassium	Iron
Sodium	Hydrogen
Calcium	Copper
Magnesium	Mercury
Aluminum (Aluminium)	Silver
Zinc	Gold

Experiments to show the displacement of metals from solutions of their salts, e.g.,  $\text{Zn}^\circ + \text{Cu}^{++} \longrightarrow \text{Zn}^{++} + \text{Cu}^\circ$ .

Experiments to show the displacement of hydrogen from acids and from water.

Occurrence of displacement reactions according to the position of the reagents in the activity series. Reference to the relative chemical activity of the above elements as shown by their reaction with oxygen, and by the comparative ease of reduction of their oxides.

#### UNIT VII. REACTIONS INVOLVING IONIZED SUBSTANCES

(6 periods)

- (1) Represent typical reactions involving electrolytes by ionic equations and discuss the factors which determine when reactions will go to completion, especially (i) the withdrawal of ions from solution, (ii) the escape of a gas, (iii) the relative activity of the elements. The following are representative reactions:

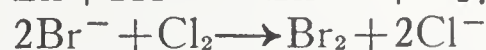
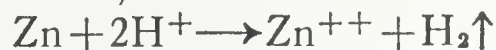
- (i) The formation of precipitates,



- (ii) The formation of un-ionized molecules or weak electrolytes, or gaseous products,



- (iii) Displacements,



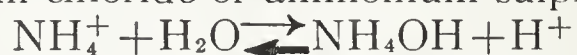
- (2) The hydrolysis of salts, as illustrated by an experimental study of the action of litmus or bromthymol blue on aqueous solutions of:

- (i) Salts of a strong base and a weak acid, e.g., potassium carbonate or sodium acetate.





- (ii) Salts of a weak base and a strong acid, e.g., aluminum chloride or ammonium sulphate.

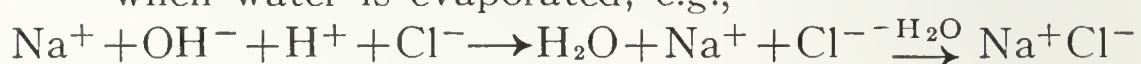


- (iii) Salts of a weak acid and weak base, e.g., ammonium acetate.

The student should understand this principle well enough to apply it to any simple salt.

*Note:* Solutions of the salts of strong acids and strong bases, such as sodium chloride, do not hydrolyze since no hydrogen or hydroxyl ions are removed from the solution to form undissociated molecules.

- (3) An experiment to show the neutralization reaction between an acid and a base; the products of the reaction are water and a salt which remains as a residue when water is evaporated, e.g.,



Demonstration of neutralization as a quantitative reaction between an acid and a base brought about by the combination of hydrogen ion with hydroxyl ion to form water. Titration of acids and bases.

#### UNIT VIII. THE CONCENTRATION OF SOLUTIONS

(5 periods)

- (1) Representation of the concentration of solutions in the following ways:

- (i) Weight of solute dissolved in 100 grams of solvent;
- (ii) Per cent by weight of solute; i.e., the number of grams of solute per 100 grams of solution;
- (iii) Number of gram-molecular weights (moles) of solute per litre of solution (molarity);
- (iv) Number of gram-equivalent weights of acids and bases per litre of solution (normality). Calculation of gram-equivalent weights for HCl, H<sub>2</sub>SO<sub>4</sub>, NaOH, and Ca(OH)<sub>2</sub>.

*Note:* The volumes of fluids are given in litres (l.) and millilitres (ml.). The ml. and the cc. are defined differently, and are not exactly equal.

- (2) Problems involving the conversion of a concentration expressed in one of these ways to the concentration expressed in any of the others. The calculation required for the preparation of a dilute acid solution of a desired concentration from the solutions in stock acid bottles, making use of the density and purity given on the label.

- (3) Experiments and calculations involving neutralization:

- (i) To find the normality of one solution in a titration where the normality of the other is known ( $N_1V_1 = N_2V_2$ ).
- (ii) To find the normality of a solution which reacts



in a titration with a known weight of pure acid or base dissolved in water.

- (iii) To find the volume of an acid (or base) of known concentration required to neutralize a given weight of a pure base (or acid).

*Note:* Repetition of experimental work already covered in Grade 12 is left to the discretion of the teacher. All experimental work listed in this Grade 13 course, however, will be required for examination purposes.

*Note:* Teachers should feel at liberty to teach the following topics in any order they may prefer. It is suggested, however, that Group I be studied first, followed by Group VII, and from the study of these two extreme groups the orderly arrangement of the elements together with the important similarities and differences may be noted. While some of the work covered may seem a review, it is intended to correlate the data into a systematic study of the periodic classification.

Where commercial preparations are required, emphasis should be placed on chemical principles, and students are not required to reproduce diagrams of either the plant or the commercial apparatus except where it is specifically stated that a diagram is required.

The metallurgical processes required in the following sections may be taught as a unit rather than with the individual elements.

UNIT IX.  
GROUP I A,  
SODIUM AND  
POTASSIUM

(8 periods)

- (1) The discussion of the preparation of sodium by the electrolysis of fused sodium chloride. It should be again pointed out that electrical conductance of fused salts is evidence of their ionization even before they are dissolved in water.
- (2) Experiments to show:
  - (i) the action of sodium and potassium on water;
  - (ii) the use of sodium carbonate (a) to produce sodium hydroxide from lime, (b) to soften water;
  - (iii) the production of potassium nitrate from sodium nitrate and potassium chloride.
- (3) The production of sodium hydrogen carbonate (sodium bicarbonate) and sodium carbonate by the Solvay process. Demonstration experiment.
- (4) The commercial production of sodium hydroxide, chlorine, and hydrogen by the electrolysis of sodium chloride solution. (*Diagram is required* to show the method of separating the products at each electrode).
- (5) The uses and properties of: sodium hydroxide, sodium chloride, sodium carbonate, sodium hydrogen carbonate, sodium nitrate, sodium thiosulphate, potassium nitrate, potassium permanganate.

*Note:* In this and subsequent sections where uses and properties are considered together, an attempt

should be made to show, wherever possible, upon what properties the uses depend.

- (6) Reference to the similarity of sodium and potassium compounds.

UNIT X.  
GROUP I B,  
COPPER

(2 periods)

- (1) Properties and uses of copper.
- (2) Concentration of the mineral by the froth-flotation process.
- (3) Purification of copper by electrolysis (electro-refining).

UNIT XI.  
GROUP VII,  
FLUORINE,  
CHLORINE,  
BROMINE AND  
IODINE

(8 periods)

- (1) An experimental study of chlorine, bromine, and iodine to show family relationships:
  - (i) Preparation from sodium or potassium compounds;
  - (ii) Solubility in (a) water, (b) carbon disulphide;
  - (iii) Bleaching action;
  - (iv) Relative activity as shown by displacement reactions;
  - (v) Action with sodium and with copper.
- (2) Experiments to show the action of concentrated sulphuric acid on sodium (or potassium) chloride, bromide, and iodide.
- (3) The similarities of the halogens: (i) hydrides, (ii) oxygen acids, (iii) action with metals, (iv) sodium and potassium salts.
- (4) The gradation in properties of the halogens: (i) physical state, (ii) colour, (iii) solubility, (iv) activity, (v) stability of hydrogen compounds.
- (5) A brief reference to fluorine as the most active member of this group. Properties and uses of hydrofluoric acid, sodium fluoride, and cryolite.

UNIT XII. THE  
PERIODIC TABLE

(4 periods)

The information gained from the study of Groups I and VII should form a basis for discussion of the orderly arrangement of the elements in Mendeléeff's Periodic Table. Statement of the Periodic Law. Meaning of the terms, period, group, family.

It should be explained that the periodic law and table are related to the modern atomic theory. Thus (i) elements in a family have similar arrangements of outer electrons, (ii) valence relationships depend upon the giving and taking, or sharing, of electrons to form stable electronic orbits, (iii) as the atomic numbers of the elements increase there is a recurrence of electronic distributions as successive orbits are filled, and this gives rise to a periodicity in properties.

Stress should be placed on the importance of this periodic table in the systematic study of chemistry.

UNIT XIII.  
GROUP II A,  
MAGNESIUM  
AND CALCIUM

(6 periods)

- (1) The physical properties and uses of magnesium.
- (2) Experiments to show (i) the burning of magnesium in steam, and the basicity of the oxide formed; (ii) the decomposition of magnesium carbonate on heating.



- (3) Experiments to show (i) the passing of carbon dioxide into lime-water to give (a) calcium carbonate, (b) calcium hydrogen carbonate (calcium bicarbonate); (ii) the action with water of (a) calcium, (b) calcium oxide, (c) plaster of Paris; (iii) (a) hard and soft water, (b) temporary and permanent hardness of water, (c) softening of water, (d) action of soaps and the newer detergents on hard and soft water.
- (4) The commercial preparation and uses of calcium carbide and calcium cyanamide.
- (5) The properties and uses of calcium carbonate, calcium oxide, calcium hydroxide, calcium chloride, calcium sulphate hydrate.
- (6) A brief reference to the similarities in the properties of compounds of magnesium and calcium, e.g., oxides, hydroxides, carbonates.

UNIT XIV.  
GROUP II B,  
ZINC

(3 periods)

- (1) The physical properties and uses of zinc.
- (2) Experiments to show (i) the action of powdered zinc on (a) hydrochloric acid, (b) a concentrated solution of sodium hydroxide; (ii) the preparation of zinc hydroxide by the addition of a solution of sodium hydroxide to a solution of a zinc salt; (iii) the amphoteric nature of zinc hydroxide as shown by the addition of (a) a strong acid, (b) a strong base.
- (3) The properties and uses of zinc oxide, zinc sulphide.

UNIT XV.  
GROUP III,  
ALUMINUM

(5 periods)

- (1) The metallurgy of aluminum (Hall's electrolytic process); *diagram required*.
- (2) The physical properties and uses of aluminum.
- (3) Experiments to show (i) the action of acids and of a strong base on aluminum; (ii) the precipitation of aluminum hydroxide and a demonstration of its amphoteric nature by the addition of (a) a strong acid, (b) a strong base; (iii) the reaction of a solution of aluminum sulphate or of alum with a solution of sodium hydrogen carbonate.
- (4) A discussion of the properties and uses of aluminum sulphate or of alum (i) in foam-type fire extinguishers, (ii) in clearing turbid water, (iii) as a mordant.

UNIT XVI.  
GROUP IV,  
CARBON, SILICON,  
TIN AND LEAD

(2 periods)

- (1) A brief reference to the position of these elements in the Periodic Table as mid-way between Group I and Group VII.
- (2) The transition from non-metallic carbon to metallic lead within the family, as revealed by (i) physical properties, (ii) acidic or basic properties of their oxides.
- (3) Reference to the materials used in the commercial production of glass.



UNIT XVII.  
GROUP V,  
NITROGEN,  
PHOSPHORUS,  
ARSENIC,  
ANTIMONY AND  
BISMUTH

(7 periods)

- (1) An experimental review of ammonia: (i) laboratory preparation, (ii) solubility, (iii) reaction with water and basic properties of its aqueous solution.
- (2) The industrial production and uses of ammonia (Haber process).
- (3) Experiments to show the oxidizing action of concentrated nitric acid on (i) carbon, (ii) sulphur, (iii) copper.
- (4) A demonstration of the properties of the red and yellow allotropes of phosphorus to show (i) physical properties, (ii) kindling temperatures, (iii) solubilities in carbon disulphide.
- (5) An experiment to show the burning of phosphorus in air.
- (6) The preparation of the oxides of phosphorus, and the formation of the corresponding acids when these oxides react with water.
- (7) The properties and uses of (i) superphosphate of lime, (ii) lead arsenate, (iii) trisodium phosphate.
- (8) Reference to the gradual transition from non-metallic nitrogen to metallic bismuth. Similarities (in formulas only) of the oxides and hydrides within the group.

UNIT XVIII.  
GROUP VI,  
OXYGEN AND  
SULPHUR

(8 periods)

- (1) An experimental review of the preparation, properties, and uses of sulphur dioxide, sulphuric acid (contact process), and hydrogen sulphide.
- (2) Experiments to show (i) the oxidizing action of concentrated sulphuric acid on (a) copper, (b) hydrogen bromide and hydrogen iodide (see Unit XI (2) ); (ii) the dehydrating action of concentrated sulphuric acid on (a) sugar, (b) wood; (iii) the use of concentrated sulphuric acid in the preparation of other acids.
- (3) Demonstration of the use of hydrogen sulphide to precipitate the sulphides of copper, silver, zinc, lead, arsenic, and antimony from solutions of their salts. Discussion of the tarnishing of silver and of the darkening of lead-base paints.
- (4) Experiment to show the combustion of copper in sulphur vapour.
- (5) The similarity in chemical behaviour of sulphur and oxygen as shown by their union with hydrogen and metals to form sulphides and oxides respectively.

UNIT XIX.  
GROUP VIII,  
IRON, NICKEL  
AND PLATINUM

(7 periods)

- (1) The metallurgy of iron: the blast furnace, essential parts and reactions; *diagram required*. The meaning of such terms as smelting, flux, slag, pig-iron, cast iron, wrought iron, alloy, and steel. The Bessemer converter or the open-hearth furnace.
- (2) Some important iron alloys, e.g., stainless steel, tool steel, armour plate. Brief reference to some of the important alloying elements such as nickel, chromium, tungsten, vanadium, used to make iron alloys.

- (3) The tempering and hardening of steel.
- (4) The properties and uses of nickel and platinum.
- (5) Experiments to show (i) the preparation of an iron (II) salt (in solution) by the action of dilute hydrochloric acid on iron; (ii) the preparation of an iron (III) salt (in solution) by heating hydrochloric acid with iron (III) oxide; (iii) the precipitation of iron (II) hydroxide and iron (III) hydroxide from their corresponding salt solutions; (iv) the change from iron (II) compounds to iron (III) compounds as shown by (a) the action of oxygen and water on iron (II) hydroxide, (b) the action of chlorine on a solution of iron (II) chloride; (v) a change from iron (III) compounds to iron (II) compounds by the action of a reducing agent such as iron, zinc, or tin (II) chloride.

#### UNIT XX. OXIDATION AND REDUCTION

(5 periods)

- (1) Review (i) oxidation as the direct union with oxygen (experimentally, the burning of magnesium in oxygen); (ii) reduction as the removal of oxygen (experimentally, the reduction of copper (II) oxide with carbon).
- (2) By reference to the experimental work of Unit XIX (5), oxidation and reduction can be considered in terms of a loss and gain of electrons (a change in valence). It should also be stressed that the two processes must always occur simultaneously.
- (3) Oxidation and reduction illustrated by (i) the direct union of a metal with any non-metallic element; (ii) displacement reactions. Equations for all reduction-oxidation (redox) reactions encountered previously should be analysed to show the changes in oxidation states (numbers).
- (4) Experiments such as the following to illustrate additional redox reactions:
  - (i) the action of hydrogen peroxide on freshly precipitated lead sulphide; (ii) the production of iron by the "thermite" process; (iii) the reduction of potassium permanganate by sulphurous acid.

#### UNIT XXI. ION AND FLAME TESTS

(4 periods)

- (1) The detection of the following ions in solution: lead, silver, copper (II), iron (II), iron (III), aluminum, zinc, ammonium, nitrate, sulphate, chloride, bromide, iodide, carbonate. Equations are not required for tests involving the formation of complex ions.
- (2) Flame tests for sodium, potassium, calcium, and barium.

#### UNIT XXII. COLLOIDS

(4 periods)

- (1) A discussion of the nature of colloids.
- (2) Experiments to illustrate (i) the formation of a true solution, e.g., sugar and water; (ii) the formation of a colloidal dispersion, e.g., boiled starch and water; (iii) the formation of a suspension, e.g., powdered calcium



carbonate and water; (iv) the rate of sedimentation according to particle size.

- (3) A comparison of true solutions, colloids, and suspensions, with respect to (i) particle size, (ii) action of filtering, (iii) visibility of particles, (iv) Brownian movement, (v) Tyndall effect.
- (4) Types of colloidal dispersions and suspensions, with at least one example of each type where possible, e.g., dust and smoke are examples of a solid (dispersed phase) in a gas (dispersing medium).
- (5) An experiment with kerosene, water and soap to show the meaning of emulsion and emulsifying agent.
- (6) Practical applications of colloid chemistry; (i) action of soap in cleaning; (ii) the making of jellies; (iii) the froth-flotation process; (iv) the Cottrell precipitator.

### UNIT XXIII. ORGANIC CHEMISTRY

(18 periods)

*Note:* Structural formulas are required only for those compounds whose names are marked with an asterisk (\*).

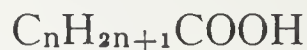
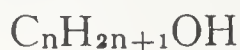
#### A. *Scope and Nature of Organic Chemistry*

- (1) The division of chemistry into organic chemistry and inorganic chemistry. Organic chemistry is the chemistry of the compounds of carbon.
- (2) The great number of organic compounds.
- (3) Characteristics of organic compounds.
  - (a) The carbon atoms have the ability to link together by covalent bonds. Most organic compounds are non-ionic in nature. (Review covalence and the covalent bond and electrovalence and the electrovalent bond: Unit IV, 6)
  - (b) Organic compounds form homologous series. (These are families of compounds where each member differs from one immediately preceding or one immediately succeeding by a fixed number of carbon and hydrogen atoms.) Illustrate homology by reference to the structural formulas of the first four members of (1) the paraffin series of saturated hydrocarbons, (2) the alcohols, and (3) the acids.

(2 periods)

methane*	methyl alcohol*(methanol)	formic acid*(methanoic acid)
ethane*	ethyl alcohol*(ethanol)	acetic acid*(ethanoic acid)
propane*	propyl alcohol(propanol)	propionic acid (propanoic acid)
butane*	butyl alcohol(butanol)	butyric acid (butanoic acid)

General formula



Alcohols have characteristic properties because of the OH group, and acids have characteristic properties quite different because of the COOH group.

- (4) Chief sources of organic compounds: natural gas, petroleum, coal, plants, animals, synthesis.



## B. Some Important Classes of Organic Compounds

(3 periods)

### HYDROCARBONS

- (1) Saturated hydrocarbons. The paraffin (methane) series.

*Methane\**: a typical member; source; a rather unreactive compound because it is saturated; on complete combustion produces carbon dioxide and water.

- (2) Unsaturated hydrocarbons.

*Ethylene\**: a typical member of the ethylene series with a double bond; adds chlorine to form ethylene dichloride, adds hydrogen to form a saturated hydrocarbon, adds water to form ethyl alcohol, and polymerizes to form polyethylene (Polythene).

*Acetylene\**: a typical member of the acetylene series with a triple bond; much greater reactivity because of the triple bond; uses of acetylene. EXPERIMENT: preparation, collection, and properties of acetylene; complete and incomplete combustion.

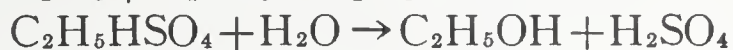
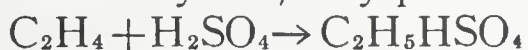
- (3) Natural gas and petroleum as sources of hydrocarbons. Fractional distillation of petroleum. Products such as naphthas, gasoline, kerosene, fuel oil and lubricating oils. Catalytic cracking of petroleum.

(2 periods)

### ALCOHOLS

- (1) Methyl alcohol\* (methanol): preparation by synthesis from carbon monoxide and hydrogen; its properties and uses.

- (2) Ethyl alcohol\* (ethanol): preparation by fermentation and fractional distillation; preparation by synthesis from ethylene, a by-product of the petroleum industry:



Properties and uses of ethyl alcohol.

- (3) Reference to the OH group as the functional group of alcohols.
- (4) Ethylene glycol\*: properties and uses.
- (5) Glycerol\* (glycerine): properties and uses.

(1 period)

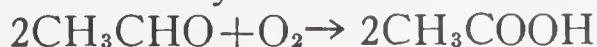
### ALDEHYDES

- (1) Reference to the functional group CHO, characteristic of aldehydes.
- (2) Formaldehyde\*: reference to its production from methyl alcohol; properties and uses.
- (3) Acetaldehyde\*: properties and uses.

(1 period)

### ACIDS

- (1) Formic Acid\*.
- (2) Acetic acid\*: properties and uses; preparation by oxidation of acetaldehyde:



- (3) Brief reference to formic and acetic acids, the first two members of the fatty acid series with the general formula  $C_nH_{2n+1}COOH$ .

(1 period)

### *ESTERS*

- (1) Preparation of an ester, e.g., ethyl acetate\*, by the action of an acid on an alcohol.
- (2) The meaning of esterification.
- (3) Occurrence of esters in fruit, food flavourings, perfumes, etc.
- (4) Brief reference to the conversion of one organic substance to another, as at Shawinigan Falls, P.Q., where acetylene (made from calcium carbide) is hydrated to acetaldehyde, which in turn is oxidized to acetic acid. This can be esterified with ethyl alcohol to give ethyl acetate.

(3 periods)

### *C. Oils and Fats and Related Compounds.*

- (1) Oils and fats are esters.
- (2) Distinction between oils (unsaturated compounds) and fats (saturated compounds).
- (3) Common examples of oils: cotton-seed oil; soya-bean oil; corn oil; fish oils such as cod-liver oil. Common examples of fats: lard; suet; butter; margarine; shortening.
- (4) Hydrogenation of oils; e.g., hydrogenation of olein to stearin (equation required). Reference to the production of margarine and shortening and solid fats required for soap making.
- (5) EXPERIMENT: the saponification of a fat to produce a soap and glycerol. Equation required.

(5 periods)

### *D. Carbohydrates.*

- (1) Composition.
- (2) Typical carbohydrates:
  - (a) Sugars: glucose; sucrose; lactose. Molecular formulas required. Reducing and non-reducing sugars. EXPERIMENT: the Fehling's test for reducing sugars.
  - (b) Starch. Molecular formula required. EXPERIMENT: the hydrolysis of starch to glucose. The action of hydrochloric acid or saliva on the hydrolysis of starch. Equation required.
  - (c) Cellulose. Molecular formula required. Natural occurrence in cotton and wood. Regeneration of cellulose to make (i) fibres such as rayon, (ii) films such as Cellophane. The nitration of cellulose to make lacquers, nail polish, and guncotton.